National Aeronautics and Space Administration

Educational Product	
Educators & Students	Grades 5–12

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Educational Brief

CASSINI SCIENCE INVESTIGATION

Lightning in a Planetary Atmosphere

Objective

To reproduce and study in the classroom phenomena analogous to the "flash-bang" of lightning and thunder. The observation of lightning in a planetary atmosphere indicates that active meteorology is occurring.

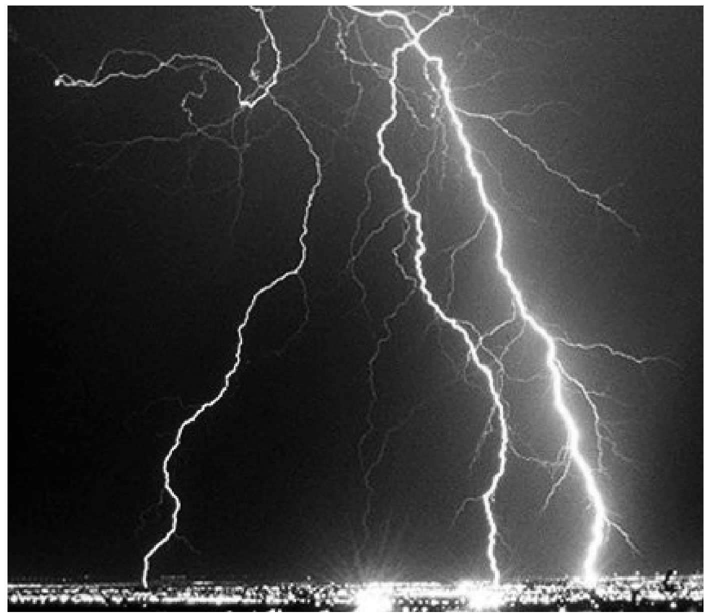
Time Required: Less than 1 hour

Saturn System Analogy: The search for lightning on Saturn and Titan

Keywords: AM Radio, Lightning, Thunderstorm, Whistler

MATERIALS

- AM radio with extending antenna (available at most variety, department, and consumer electronics stores for $5.00 and up)
- Electric barbecue lighter (available at many variety, grocery, or picnic or camping-supply stores for about $5.00). *Cigarette lighters will work but do not have as strong a spark as barbecue lighters.*
- Optional: Tesla coil, Van de Graaf generator, Wimshurst generator, or even an automobile coil. *Be careful as these can make large sparks for this demonstration!*
- Optional: oscilloscope

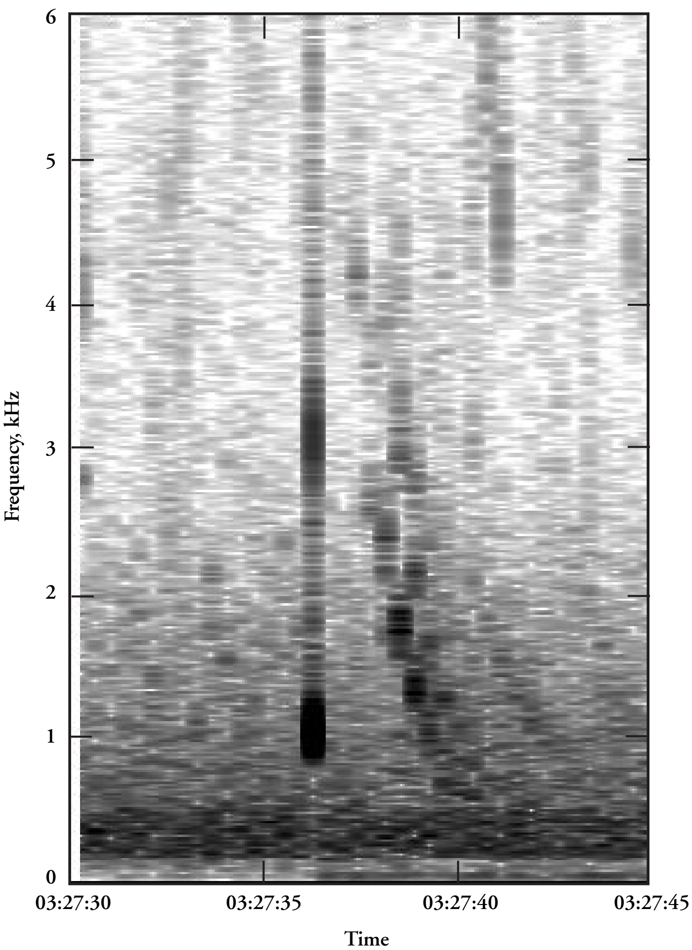


Inside a thundercloud on Earth, an enormous electrical charge builds up. When it discharges, there is a blinding flash as lightning zigzags between the ground and the cloud.

Discussion

Lightning is a phenomenon most people have experienced. The glaring flash of light is followed by booming thunder rolling across the landscape. Sometimes the bolt of lightning is seen and followed by thunder, while at other times the lightning is so distant that flashes are the only evidence of storm activity. On a smaller scale, anyone walking across a carpet on a dry (low humidity) day can produce miniature lightning. These static discharges, usually felt, are sometimes seen (in the dark), and often heard.

The phenomenon, whether spanning kilometers of atmosphere from cloud to ground or millimeters from fingertip to doorknob, has the same origin: moving electrons. Negatively charged electrons moving across a spark gap, large or small, excite atoms in the air, making them glow briefly and heating the air. The hot air expands rapidly to generate thunderclaps and static discharge snaps.



This is a picture of radio noise generated by lightning in Earth's atmosphere, as observed by Cassini's Radio and Plasma Wave Science instrument. The vertical stripe shown here just after 03:27:36 is the radio emission of a lightning discharge and is called a 'spheric (or atmospheric). Notice that the discharge generated radio noise at many frequencies from about 0.8 kHz to beyond 6 kHz, with signal strength especially strong near 1 kHz and 3 kHz. A lightning discharge also generated the curved signal, called a whistler, in the frequencies between 0.5 kHz to about 2.5 kHz that spans 03:27:38 to 03:27:41.

The acceleration of electrons during the discharge also produces radio frequency emissions. Just as lightning appears white because it generates (roughly) equivalent portions of all colors, radio emission from lightning likewise covers a broad radio frequency range.

The mechanism that separates electric charge in an atmosphere, leading to lightning, tells meteorologists about conditions in that atmosphere. Simply finding lightning alerts meteorologists that there are strong vertical movements in an atmosphere.

The Cassini spacecraft carries its Radio and Plasma Wave Science (RPWS) instrument to study, among other things, radio emissions from planets and plasma interactions. Lightning is among the emissions it can study. Lightning has distinctive radio emissions, called 'spherics (or atmospherics) and, because of their distinctive sound when the radio emission is converted to sound, "whistlers." A 'spheric is a brief burst of static across many frequencies.

A whistler presents the curved signal in the illustration and is the result of a 'spheric that has been modified during its journey to the receiver. The curvature indicates that higher frequencies of the whistler reach the receiver before the lower frequencies. This is a property of the propagation of low-frequency radio signals in a magnetized plasma (a gas of charged particles with an imbedded magnetic field — in this case, the magnetic field is that of Earth). The whistler waves propagate more or less along the magnetic field, and the longer they propagate, the larger will be the difference in arrival times between the high and low frequencies.

An analog to the RPWS receiver is the common AM radio receiver found in cars, boom boxes, stereo systems, and personal sound systems. Whereas an AM receiver is intended to select a single frequency (station) for listening, the RPWS receiver is designed to detect and record many frequencies at once.

This demonstration uses an everyday AM radio and a barbecue lighter to illustrate the broadband radio emission of lightning 'spherics.

Procedure

Turn on the AM radio and adjust the dial to the extreme low frequency end of the receiver (near 530 kHz). The volume can be set fairly high; most likely static will be heard. (If a station broadcasts at this frequency, adjust the tuner to the lowest frequency on which only static can be heard.) Place the igniter end of the barbecue lighter next to the antenna to hear the signal more easily. Trigger the lighter. Note the spark discharge inside the igniter, the snap of its miniature thunder, and the click from the radio speaker. The click is a radio emission from the discharge. (The sound of the trigger sometimes makes the snap and click hard to distinguish.)

Follow the same procedure at additional frequencies (where there is static, not a broadcasting station signal) up the radio spectrum to its maximum at about 1600 kHz. Does the click from the speaker sound different at different radio frequencies? If so, how does the sound change as you proceed up the AM dial (to higher frequencies)?

An oscilloscope attached to the radio receiver, a microphone, and/or a light sensor and set for a single sweep can record the characteristics of the barbecue lighter/thunderstorm. Some creative thinking will allow the sound of the trigger and the snap of the "thunder" to be separated in the recording. There are several possibilities.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

10. Understands forces and motion.

LEVEL 4 (GRADES 9–12)

Knows that materials that contain equal proportions of positive and negative charges are electrically neutral, but a very small excess or deficit of negative charges in a material produces noticeable electric forces.

Knows that the strength of the electric force between two charged objects is proportional to the charges (opposite charges attract whereas like charges repel), and, as with gravitation, inversely proportional to the square of the distance between them.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

Knows that tools (e.g., thermometers, magnifiers, rulers, balances) can be used to gather information and extend the senses.

LEVEL 2 (GRADES 3–5)

Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world.

Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Lightning in a Planetary Atmosphere

Procedure

1. Turn on the AM radio and adjust the dial to the extreme low frequency end (530 kHz). If there is a station transmitting at that frequency, set the radio to the lowest frequency at which no station broadcasts.

2. Set the volume at a high level so that static is heard.

3. Place the igniter end of the barbecue lighter close to the antenna.

3. Trigger the lighter.

5. Repeat the procedure for various frequencies up and down the AM dial.

Questions

Can you hear the click at the low frequency end?

Can you hear the click at higher frequencies?

How close to the antenna must the lighter be held so that the experimenter can hear the "snaps" on the radio?